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National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No. NAS-5-2078

ST-SB - 10 083

THE ENSURING OF RADIATION SAFETY DURING FLIGHTS OF SOVIET COSMONAUTS

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Consultants and Designers, Inc.
Arlington, Virginia
December, 1963

ST-SB - 10 083

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XIVth Intern Astron Congress
Unesco Palace, Paris
September, 1963

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ABSTRACT

A system of radiation safety measures during manned space flights provided prediction of radiation situation in outer space, measurements of the integral dose and dose rate directly on a space ship-satellite, biological dosimetry of cosmic radiation as well as use of pharmaco-chemical antiradiation agents in case of emergency. The results obtained have made it possible to estimate positively the radiation safety system of manned space flight.

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During flight along the orbit of the ship Vostok a space pilot is subject to the action of primary cosmic radiation (galactic rays and bremsstrahlung produced at interation of

outer radiation belt's/electrons with the ship's hull. Nor excluded is the possibility of small irradiation protons of the inner radiation belt discending for instance to height of 230 - 320 km in the region of the Brazilian magnetic anomaly.

According to Ś. N. Vernov et al. [1] , V. E. Nesterov et al. [2] , at altitudes of 180 - 340 km for an orbital inclination of 65°, approximately 90 per cent of the absorbed dose result from primary cosmic radiation and 10 per cent are due to Earth's radiation belts. It should be noted that strongly ionizing heavy nuclei, which, can cause nuclear disintegration stars in the biological object, constitute a part of primary cosmic radiation. Taking into account the biological peculiarities of the action of the heavy component, one should expect that the biological effectiveness of radiation of this type will be much higher than the effectiveness of X-rays and gamma-rays.

Measurements carried out aboard spaceships-satellites II-V and Vostok have shown that at these heights the integral 24-hour radiation dose varies within 8-15 millirads. It is quite evident that even if the high biological effectiveness for the heavy component of primary cosmic radiation is taken into account, the radiation dose received during shorttime flights at heights of 180-250 km is not dangerous.

At those heights protons produced during solar flares constitute a real threat to cosmonaut's health. Solar protons have energies from several Mev to 700 Mev, and in some cases

their energy can reach several Bev.

After mighty solar flares the intensity of cosmic rays at great distances from the Earth beyond the magnetic field is increased by thousands and even tens of thousands times. This leads to an enormous increase of doses up to lethally dangerous levels on the order of 500 rad. In orbits of the Vostok-type ships, where the shielding effect of the Earth's magnetic field is felt, the irradiation dose decreases, reaching several tens of rads per flare. Taking into account that protons of solar flares act in a complex reaction or against the background of other flight factors increasing radiation, there are grounds to suppose that under these conditions the dose of several tens of rad will be dangerous for the astronaut's health.

Production of solar flares occurs without any definitely expressed regularity in time. Therefore, the probability of getting into a flare of different intensity depends on average probability of its appearance and on duration of flight.

Besides, protons of solar flares, and the ionizing radiation caused by the American high-altitude explosion over Johnson Island in the Pacific Ocean on July 8, 1962, constituted a grave danger for space pilots A.G. Nikolayev, and P.R. Popovich. Taking the above mentioned into account the system of measures guaranteeing radiation safety during flights of ships Vostok provided for:

— prediction of radiation situation in outer space;

— measurement of the integral dose and the dose rate directly on ship-satellite;

— biological dosimetry of cosmic radiation;

— use of pharmaco-chemical antiradiation agents under conditions of emergency.

To predict radiation situation in outer space the "solar service" was established to observe the state of solar activity. This service functioned before and during flight. Astrophysical observatories and heliophysical stations situated at different points of the Soviet Union conducted continuous optical, magnetic and radio observations of the Sun. Moreover, direct measurements of radiation intensity in the upper atmosphere were carried out by means of instrumentation raised on balloons. Balloon flights were accomplished six-seven times during 24 hours at different places of the USSR, including polar regions. The information, obtained about the radiation situation in outer space enabled the organizers of flight to take decisions on its accomplishment and on the subsequent program.

To increase radiation safety the ships had a shield of necessary design to protect the cabin against penetration of any formation of cosmic radiation, and which, to a considerable degree, protected the cabin against the effect of radiation generated by the nuclear explosion in outer space.

The astronauts were provided with special radioprotective compounds for the case of sharp deterioration in the radiation situation for prophylaxis of its injuring effect.

Dosimetric control on Vostok 1 and Vostok 2 spaceships was carried out by means of individual dosimeters ILK, IFK and thermolunimescent glasses. The total dose for flight was less than mrad in Y.A. Gagarin's flight and 12 mrad in G.S. Titov's flight.

In connection with the increase of flight time of Vostok 3 and Vostok 4 spaceships, special dosimetric instrumentation was installed on board and whose telemetry readings were transmitted to ground observation points. Besides, the set of individual dosimeters was extended. Apart from dosimeters with which Yu. A. Gagarin and G.S. Titov were provided, A.G. Nikolayev and P.R. Popovich had DKP-50 nuclear photoemulsions, etc.

According to data of on-board dosimeters, the total dose during the Vostok 3 flight was 43±1 mrad, and during the Vostok 4 flight it was 32 ±1 mrad (S.N. Vernov, I.A. Savenko et al. [3]).

Readings of individual dosimeters DKP-50 did not go out of the limits of errors caused by self-discharge.

According to data obtained by means of individual dosimeters placed on astronauts, the absorbed dose was from

48 to 64 mrad for A.G. Nikolayev, and from 37 to 46 mrad for P.R. Popovich (see I.B. Kerim-Markus et al. [4]).

The set of ionizing radiation detectors situated in the bioblock has made it possible to estimate the radiation conditions in which biological experiments were conducted. According to the data of the study of nuclear photoemulsions and scintillation dosimeters, the integral dose in places of location of bioblocks during flight on the ship Vostok 3 was 56 $\pm$ 8 mrad, and on Vostok 4 it was 45 $\pm$ 7 mrad. The contribution of charged particles to the integral dose was about 40 per cent, and approximately two thirds of this contribution corresponded to heavy nuclei ($Z>1$). According to the data of dosimeters IFK and ILK the total during the flight was about 50 - 60 mrad (V.N. Lebedev, V.S. Norozov et al.[5]).

Thus the average dose rate of radiation during flights of space ships Vostok 3 and Vostok 4 was 13 $\pm$ 2 mrad per 24 hours, i.e. noticeably exceeding the dose rate observed on Vostok 1 (7.2 mrad/24 hours) and on Vostok 2 (8.4 mrad/ 24 hours). The increase of the dose rate may be accounted for by possible residual radiation caused by the high-altitude nuclear explosion on July 8, 1962.

As evident from the above-cited results of measurements, integral doses obtained by different methods agree with one another within the measuring errors. As is well known, these doses do not exceed the norm established for persons working with penetrating radiation sources, and are not dangerous to human health.

Alongside the above mentioned instrumentation, different biological objects were carried aboard spaceships: airdry seeds of plants (wheat, pea, onion, pine, cabbage, carrot, etc.) microspores of Tradescantia paludosa, lysogenic culture of E. coli K-12 (λ) , Drosophila melanogaster, human cancer cells, eggs of swine's Ascaris. These objects were used for biological dosimetry of cosmic radiation, and for investigation of the injuring effect of flight factors, including the ionizing radiation, on hereditary structures and physiological functions of a cell of an organism.

It should be noted that the results or radiobiological investigations agree quite satisfactorily with the data of physical measurements. These experiments have shown that injuring effects of flight factors on hereditary structures of some objects may be revealed by means of genetic tests. For instance, different disturbances of mitosis were observed in sprouts of wheat (V.V. Khvostova et al.[6]) in microsporses of Tradescantian (N. L. Delone et al.[7] an inducing effect is detected in lysogenic bacteria, (N.N. Zhukov-Verezhnikov et al.[8]. It should be emphasized that quantitatively these effects are not great. At the same time the use of physiological methods of research has not permitted to reveal any expressed changes typical of radiation injury in life functions of different objects.

The revealed genetic changes are probably caused by the effect of a totality of flight factors, including the ionizing

radiation in small doses. The possibility is not excluded that such factors, as vibration, accelerations etc. are sensitizers for some objects, as far as the effect of cosmic radiation is concerned. In our opinion, the assumption that the above mentioned injuries of hereditary structures are specific and are caused by the heavy component of galactic rays is less substantiated. It is quite evident that the causes and machanism of genetic disturbances observed in some biological objects under the influence of flight factors require further investigations.

General clinical observations and special laboratory examinations of Yu. A. Gagarin, G.S. Titov, A.G. Nikoayev and P.R. Popovich regularly conducted after completion of flight also confirm convincingly that during these flights there was no negative effect of cosmic radiation on space pilot's health.

Thus, the results ob tained permit to estimate positively the system of measures used to guarantee radiation safety during manned space flights on board ships of the Vostok type.

***** THE END *****

Redrafted from a Preprint
available at the IAF Congress
in Paris, September 1963

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